Design & Construction of Log Structures

Acceptance of Traditional, but "Alternative", Materials and Methods of Assembly

Historic Perspective

- Ancient settlements date to 700 BC
- Use of indigenous materials
- Relatively simple, often one room

Post Office, MN

1785 hewn log cabin

Early Log Structures

- Full length logs extended at corners to delay the effect of decay
- Mud, straw, oakum, moss, and other materials used to seal between logs

Evolution of Technology

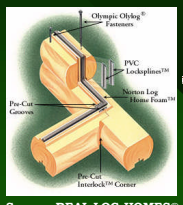
- Organic finishes from local ingredients
- 1920 -- Pre-cut log home "kits"

1911 vintage (WI)

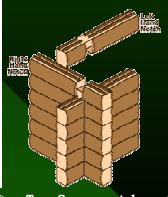
1891 vintage (CO)

Modern Log Systems

- Proprietary solutions to seal out air & moisture



Source: REAL LOG HOMES®



Typ. Square notch corner

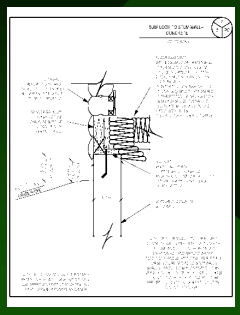
Source: Heritage Log Homes

Modern Log Structures

- Incorporate sophisticated design & engineering
- Use modern finishes
- Offer variety of corner & log style

Corner photos courtesy of Southland Log Homes Inc.

Principles of Construction



Detail courtesy of Southland Log Homes Inc.

Same as conventional:

- Project planning & preparation
- Design loads and deflection criteria
- Plumb, square and level construction
- Receiving, handling, and protecting materials

Tradition Mixes with Convention

- Conventionally built systems except for log walls and log framing members…
  - Foundations, subfloors, partition walls, windows, doors, roofing
  - Plumbing, electrical, mechanical

There's only one right way to build a log home…

Per the blueprints, details, and instructions (construction manual) provided with the log package.

Building System Variations

Structural headers and exterior flashing protect openings

Settlement allowance over openings is a function of the building system.

- Wall-Logs: Species, size, shape, treatments, MC
- Extent of processing: Lineal length, pre-cut, handcrafted
- Joinery: Corners, butt joints, openings, sealants
- Connections and fastening patterns
- Accommodating movement: Compaction and shrinkage

The Log Home Industry

Annual stats taken from industry publications:

- Over 25,000 log homes built from North American producers

Types of Producers	# of Co.s	Annual Production
Handcrafters	200-300	Up to 100 units/year; 85% < 25/yr.
Manufacturers of milled products	270-325	Up to 1000 units/year; 90% < 200/yr.

A Market Snapshot

- Over 400,000 log homes exist in North America.
- 7% of custom-built housing market
- $1.4 billion market
- Annual production of log home packages increased 41% from 1988 to 1995 and 46% since.

-- Log Home Living Institute survey, 2001

Courtesy of Kuhns Bros Log Homes, Inc.

1977: The LHC First Meets

22 Charter Members form the Log Homes Council to respond to code issues

- Develop and promulgate standards of quality and safety throughout the log home industry
- Disseminate information about developments in the log home industry to regulatory bodies, governmental agencies, the press, and the general public

Building Systems Magazine's 2001 Excellence in Model Home Design –

Appalachian Log Structures, Inc.

1980: ASTM D-3957

"*Standard Methods for Establishing Stress Grades for Structural Members Used in Log Buildings*"

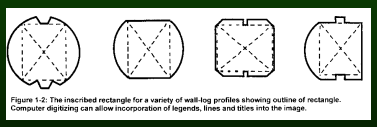


Figure 1-2: The inscribed rectangle for a variety of wall-log profiles showing outline of rectangle. Computer digitizing can allow incorporation of legends, lines and titles into the image.

- Culmination of a 3-yr effort financed by the LHC
- Defines Wall-Logs and Sawn Round Timber Beams
- Establishes the method used to generate design stress values used for structural analysis

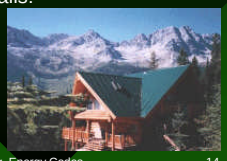
1983: Thermal Testing

± 2 yrs in development, monitoring and evaluation

–National Bureau of Standards report demonstrates the thermal benefits of log and other heavy mass walls

Six 20'x20' test buildings w/90" walls:

- 2x4 insulated R-12
- 2x4 without insulation R-4
- masonry internally insulated R-14
- un- insulated masonry R-5
- 7" solid square log R-10
- masonry externally insulated R-12



1984: Mandatory Log Grading

- LHC recognized as a rules-writing grading agency per NES QA-154
- Training sessions held to certify plant personnel and third-party inspectors (QSA)
- Log grading implemented using proprietary grade marks and/or Certificates of Inspection

1989: Thermal Mass

Section 502 of the Model Energy Code…

502.2.1.1.2 Mass walls. When the thermal mass of the building components is considered, the U_o for exterior walls in Section 502.2.1.1 and having a heat capacity greater than or equal to 6 Btu/ft² · °F [1.06 kJ/(m² · K)] of exterior wall area shall be less than or equal to the values in Table 502.2.1.1.2(1), 502.2.1.1.2(2) or 502.2.1.1.2(3) based on that U_o required for walls with a heat capacity less than 6 Btu/ft² · °F [1.06 kJ/(m² · K)] of exterior wall area as determined by Equation 5-1 in Section 502.2.1.1 and Figure 502.2(1).

Note: Masonry or concrete walls having a mass greater than or equal to 30 lb/ft² (146 kg/m²) of exterior wall area and solid wood walls having a mass greater than or equal to 20 lb/ft² (98 kg/m²) of exterior wall area have heat capacities equal to or exceeding 6 Btu/ft² · °F [1.06 kJ/(m² · K)] of exterior wall area.

The heat capacity of the wall shall be determined as follows:

$$HC = w \times c$$

where:

HC = Heat capacity of the exterior wall, Btu/ft² · °F [kJ/(m² · K)] of exterior wall area.

w = Mass of the exterior wall, lb/ft² (kg/m²) of exterior wall area is the density of the exterior wall material, lb/ft³ (kg/m³) multiplied by the thickness of the exterior wall, ft (m).

c = Specific heat of the exterior wall material, Btu/lb · °F [kJ/(kg · K)] of exterior wall area as determined from Chapter 24 of the ASHRAE *Handbook of Fundamentals*.

Thermal mass credit when density ≥ 20 lb/ft²

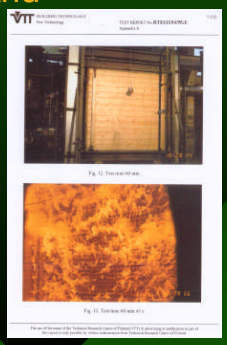
1995: Assistance to HUD

- Request for guidance in the review and acceptance of HUD Structural Engineering Bulletins
- LHC Guide for Construction Manuals
- A new level of acceptability of log homes in Federally-insured mortgage programs

1997: Urban-Wildland Interface Code

"Log Wall Construction" defined and recognized as a one-hour-rated fire-resistive exterior wall

"…where the smallest horizontal dimension of each solid wood member is at least 6" (152mm)."



Test report photos at the 60 -minute mark, courtesy of HonkaHomes USA, Inc.

In the New Millennium…

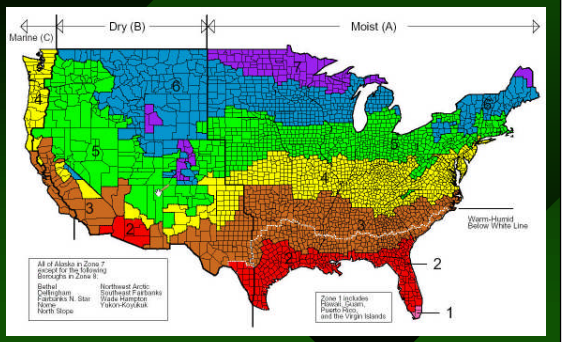
58 LHC Members

- Subscribe to the Code of Ethics
- Represent about 20% of all North American log home producers
  BUT
- Produce 50% or more of new log home construction
- Sponsors of Whole Wall Testing at Oak Ridge National Labs
- Active in development of ICC 400

ICC400 *Standard for the Design and Construction of Log Structures*

Analyzing Log Properties

- Log grading & moisture content
- Design values and section properties
- Fire-resistance ratings
- Settling provisions



Moisture Content by Climate Zone

FPL-RN-0268, Equilibrium Moisture Content of Wood in Outdoor Locations in the United States and Worldwide

by IECC Thermal Zones

Zone:	1	2	3	4	5	6	7	8	9
Average by Zone:	13.2	12.6	12.3	13	12.8	12.6	14.3	14.6	No data

by IECC Climate Zones

	Dry	Moist	Warm-Humid	Marine
Minimum by Zone:	8	12	13	13
Average by Zone	10	13	14	15
Maximum by Zone:	13	15	15	17

ICC400 *Standard for the Design and Construction of Log Structures*

Analyzing Log Properties

- Log grading & moisture content
- Design values and section properties
- Fire-resistance ratings
- Settling provisions
- Thermal envelope

FPL-RN-0265, Equilibrium Moisture Content of Wood in Outdoor Locations in the United States and Worldwide

by IECC Thermal Zones

Zone	1	2	3	4	5	6	7	8	9
Average	13.2	12.6	12.3	13	12.8	12.6	14.3	14.6	No data

by IECC Climate Zones

	Dry	Moist	Warm-Humid	Marine
Minimum by Zones	8	12	13	13
Average by Zones	10	13	14	15
Maximum by Zones	13	15	15	17

	Specific Gravity (G) at Exterior EMC Average EMC by Zone*:			
	Dry	Moist	Warm-Humid	Marine
SG, unconditioned wood (ASTM D2555)	10	13	14	15
Cedar, Northern white	0.29	0.306	0.303	0.302	0.302
Cedar, White (WC), Cedar: Eastern white-Canadian, balsam poplar (North), black cottonwood (North)	0.3	0.317	0.314	0.313	0.312
Cedar: Atlantic white, Cedar, Red (Western, RC), Cedar: Western red (WRC), Cedar: Western red-Canadian (WRC-N), Black Cottonwood, subalpine fir	0.31	0.328	0.325	0.324	0.323
Aspen: Lagetooth-Canadian, Cedar: Port Orford, Fir: Pacific silver, Hem-Fir (HF), Hemlock: Eastern, Pine: Lodgepole, Pine: Ponderosa (PP), Pine: Red-Canadian (RP-N), redwood (Old Growth)	0.39	0.419	0.414	0.413	0.411
Ash: Black, Douglas fir: Coast, Douglas fir: Interior North, Douglas fir-Canadian, Douglas Fir-Larch (DFL)	0.45	0.489	0.483	0.481	0.479
Birch: Paper, Larch, western, Southern Pine (SP), Mixed: Southern Pine (MSP), Tamarack-Canadian	0.48	0.524	0.517	0.515	0.513
Ash: White, Pine: Longleaf (LLP), Pine: Slash (SHP)	0.54	0.597	0.588	0.585	0.582
Hickory: Bitternut, Oak, White (WO)	0.62	0.696	0.684	0.68	0.675
Oak, Live	0.81	0.671	0.659	0.656	0.652

*Assuming wood is at 30% MC at fiber saturation. Wood species groups per Log Homes Council Grading Programs

Equations per Wood Handbook, FPL: Calculation of Specific Gravity at Varying EMC:

Eq. 3-5: $G_m = G_b / (1 - (0.265 * G_b))$ $\alpha = (MC_{FSP} - EMC) / MC_{FSP}$

G_b = specific gravity based on green volume (ASTM D2555)

Integral Insulation & Thermal Mass: Solid wood walls having a mass greater than or equal to 20 psf

SG, Grn	Weight (psf) per Inch of Log Thickness Average EMC by Zone*: Dry 10	Moist 13	Warm-Humid 14	Marine 13	R-Value per Inch of Log Thickness Average EMC by Zone*: Dry 10	Moist 13	Warm-Humid 14	Marine 13
0.29	1.75	1.8	1.81	1.83	1.6	1.55	1.53	1.51
0.3	1.81	1.86	1.88	1.9	1.56	1.51	1.49	1.47
0.31	1.88	1.93	1.94	1.96	1.51	1.46	1.45	1.43
0.39	2.4	2.46	2.48	2.51	1.24	1.2	1.18	1.17
0.45	2.8	2.87	2.9	2.92	1.09	1.05	1.04	1.03
0.48	3	3.08	3.11	3.13	1.02	0.99	0.98	0.97
0.54	3.41	3.51	3.54	3.57	0.91	0.88	0.88	0.87
0.62	3.98	4.09	4.13	4.16	0.8	0.77	0.77	0.76
0.81	5.84	5.94	5.98	6.01	0.82	0.8	0.79	0.78

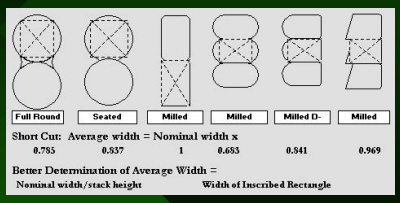
Eq 3-6: Density = 62.4 x Gm(1+EMC/100) Weight = density/12

Eq 3-7: k = SG[B+ C(MC)] +A MC = EMC

For SG >0.3, design temperature at 75° F, and MC <25% A= 0.128 B= 1.34 C= 0.028

Note the inverse relationship of mass and R-value across a range of specific gravities.

Log Wall Thickness



Full Round	Seated	Milled	Milled	Milled D-	Milled
Short Cut: Average width = Nominal width x	0.785	0.537	1	0.653	0.841	0.969

Better Determination of Average Width = Nominal width/stack height Width of Inscribed Rectangle

R-Value of Log Wall by Average Width and Specific Gravity

Specific Gravity (SG)	Average Width 5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	12 in.	14 in.	16 in.
0.29	8.99	10.61	12.23	13.86	15.48	17.11	20.36	23.61	26.86
0.3	8.76	10.35	11.93	13.51	15.1	16.68	19.84	23.01	26.17
0.31	8.56	10.1	11.64	13.19	14.73	16.27	19.35	22.44	25.52
0.32	8.37	9.87	11.37	12.87	14.38	15.88	18.89	21.89	24.9
0.33	8.18	9.65	11.11	12.58	14.04	15.51	18.44	21.38	24.31
0.34	8	9.44	10.87	12.3	13.73	15.16	18.02	20.88	23.75
0.35	7.84	9.23	10.63	12.03	13.43	14.82	17.62	20.41	23.21
0.36	7.68	9.04	10.41	11.77	13.14	14.5	17.24	19.97	22.7
0.38	7.38	8.68	9.98	11.3	12.6	13.91	16.52	19.13	21.74
0.39	7.24	8.52	9.79	11.07	12.35	13.63	16.18	18.74	21.29
0.41	6.98	8.2	9.43	10.65	11.88	13.1	15.55	18	20.45
0.42	6.85	8.05	9.25	10.45	11.66	12.86	15.26	17.66	20.06
0.44	6.62	7.77	8.93	10.08	11.24	12.39	14.7	17.01	19.32
0.47	6.3	7.4	8.49	9.58	10.67	11.76	13.94	16.12	18.3
0.5	6.02	7.05	8.09	9.12	10.16	11.19	13.26	15.33	17.4
0.51	5.93	6.95	7.97	8.98	10	11.02	13.05	15.08	17.11
0.52	5.85	6.85	7.85	8.85	9.85	10.84	12.84	14.84	16.84
0.53	5.77	6.75	7.73	8.71	9.7	10.68	12.65	14.61	16.59
0.54	5.69	6.65	7.62	8.59	9.55	10.52	12.45	14.39	16.32
0.55	5.61	6.56	7.51	8.46	9.41	10.37	12.27	14.17	16.08
0.59	5.32	6.22	7.11	8.01	8.9	9.8	11.58	13.37	15.16
0.6	5.26	6.14	7.02	7.9	8.78	9.66	11.43	13.19	14.95
0.7	4.69	5.46	6.23	6.99	7.76	8.53	10.07	11.6	13.14

Note: Above and left of the bold line, log criteria does not meet IECC requirements for heat capacity for thermal mass credit.

ICC400 Prescriptive R-values calculated at 12% EMC, including air films.

ICC 400: Structural Analysis

Building Systems Magazine's 2002 Excellence in Model Home Design – Heritage Log Homes, Inc.

- Prescriptive vs. Engineered
- WFCM as model
- Lateral loading on log walls
- Diaphragm and shear wall analysis

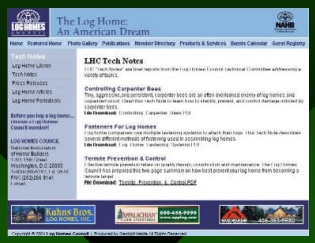
Questions?

For more information:

Log Homes Council

1-800-368-5242 x8577

www.loghomes.org



To contact Rob Pickett:
RobPickett &Associates
P.O. Box 490
Hartland, VT 05048
802-436- 1325
robpickett@vermontel.net
www.robpickettandassoc.com